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Poor Ergonomics costs but can good be made to pay?

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Abstract
The financially beneficial role that ergonomists offer is often ignored or misunderstood by the designers, engineers and technologists who create the artefacts and systems that make up our world. It is hypothesised that this is due to our limited experience as predictors and as quantifiers of the future and understanding of current design practices; essential skills for those seeking to influence change.

Historically, ergonomists have been better at investigating and understanding the responses and behaviour of people than as predictors of the future. However, the best designers, engineers and architects have taken up our insights and incorporated them into their design work. This paper offers an illustrated explanation of these issues and seeks to demonstrate how the application of one, financial predictive, technique (NPV) can encourage the adoption of an ergonomic perspective.

Systemic incidents and catastrophic failures

It is just after 8:10 on the 5th October 1999 and two trains find themselves competing to share a single section of track at Ladbroke Grove Junction. The Paddington Rail Crash is underway and its tragic consequences are unfolding. The investigating experts quickly identify the last acts, acts of omission, which "caused" the incident. Two signals set at *caution* (yellow) and one set at *danger* (red) have been passed by the train leaving Paddington Station. After a further 700M this outbound train met another, inbound.

Monthly reports detailing SPADs (Signals Passed At Danger) are published but the sixty-fifth (HSE 2005) records 27 (of which 14 are classified as "serious") for January 2005. Furthermore, re-occurrences are common, some signals are far more problematic than others. The reasons for the Paddington "accident" and its consequences have been identified as complex. A systems approach is required to resolve these undesirable properties emerging from this mass transport system. The application of ergonomics will only be one component of the systemic solution necessary.

The final allocation of financial liabilities and penalties can take many years but catastrophic failures, such as *Ladbroke Grove,* are costed and the amounts apportioned. If it was desired, the cost of the final omission, by the driver, could be balanced against the cost of reducing the likelihood of a re-occurrence or even the potential elimination of the specific risk; for example, by installing a technological *solution,* perhaps, an unoverrideable Train protection and Warning System (TPWS). This was the solution proposed following the Clapham Junction derailment (12/12/1988) which resulted in the death of 35. A proposal that was never, on discounted cost/benefit grounds, comprehensively implemented.

An ergonomist, well aware of the fallibility of human signal recognition mechanisms and associated cognitive processing, might make the suggestion to remove the human from this particular, safety critical, loop. If such a technological proposal were adopted then the cost of his/her fee would, if compared to the technological development and infrastructural costs, offer a fabulous financial return.

However, the question usually asked is; what is the magnitude of expenditure required to bring about the saving of an incident, injury or death and then the extent, or otherwise, that such costs are "acceptable". (Baker and Dunbar 2004, Dyball and King 2003 and HSE 2003). This is a complex question with both "hard" (technological) and "soft" (human) elements, probably best resolved by the adoption of a Systems approach (Porter 1991).

The fundamental non-interconnectability concept, if applied, could have prevented the *Camelford* water contamination incident when, on the 6th July 1988, a relief delivery driver pumped 20 tonnes of Aluminium Sulphate into a tank "distal, rather than proximal, to the purification plant" at the *Lowermoor* water treatment works (David and Wessely 1995 and Altmann et al 1999). An event for which the consequences for the health and well-being of the 20,000 people exposed are still emerging.

Other catastrophic failures are less public or dramatic but none-the-less devastating for the family and friends of the victim(s). Consider the near one per year death rate caused when a medical injection intended for a vein is given into the spine as was the case for Wayne Jowett in 2001 (Meikle 2001). Patently, it should not be possible to fit syringes used for intravenous drugs to the needles designed for spinal injections. This could prevent this, re-occurring "accident".

The non-interconnectability concept is obvious and common; for example in petrol nozzle diameters preventing leaded petrol being pumped into cars with catalytic converters. The conclusion that equipment should be redesigned so that such "mistakes" cannot occur is simple, basic ergonomic common sense. The cost/benefit financial case of the inclusion of ergonomists in teams seeking resolution to systems failure is easily made. However, as most of these complex systems evolve, rather than are created by a single act of design, it can be difficulty to engage with the process and convince others of the importance that the insights of an ergonomist might have. The creation of solutions to the undesirable emergent properties of multifactorial complex situations will require a Systems based approach.

Musculoskeletal and other workstation/task design issues

The modification of repetitive tasks, workstations and workplaces so that they better met standard ergonomic criteria; following accident, cumulative injury or the suspicion that such undesirable events will emerge promises, in the author's experience, rapid payback. Unfortunately, the legal and corporate identity issues associated with open publication (Porter 1995, 1998a & b) and the often *routine* nature of the traditional ergonomics applied has resulted in few published costed case studies.

Worthy (2002) undertook a trawl for such data resulting in "averages" of £19.8k, £241.9k and 7 weeks for cost, savings and payback respectively. (Stanton and Baber 2003). However, only four sets of, mathematically skewed, data are reported. For example, gearing, the financial ratio of tangible, usually productivity, savings to capital, costs range from 2.8 to 54.6 with a mean of 21.5. Ironically, given the ergonomics perspective none of the studies quoted quantified financial, workforce based, benefits. Additionally the payback measure takes no account of any cash-flows once payback has been achieved. This is a, potentially, misleading weakness if the project goes from loss to profit and back to loss; common if decommissioning costs or other residue/legacy expenses are to be expected. For longer term projects the issue of the real value of future cash-flows can be dealt with via *discounting*.

Payback is a simple, readily understood financial measure. It is the author's experience that, if payback can be shown to occur within half of the remaining financial year, then the proposal, is usually agreed to. However, if this is not so or if the Senior Management bonuses are based upon the Return on Capital Employed (ROCE) then this may not be so. For example, if the value of capital is very small, perhaps a factory containing fully discounted sewing machines, then the bonus is driven by the low cost of capital rather than the profit or turnover made by the factory or production line. In this case implementation approval may be argued for on the basis of the consideration of the ratio of capital to cost (both small); but encouraging the consideration of a wider range of potential strategic costs/liabilities can be decisive (Porter 1995).

However, in these cases the issue preventing effective, ergonomic, intervention is usually the lack of the initial telephone call/email. The organisation concerned *needs to know, what it does not know and, further more, how to get the knowledge needed to find a solution to the question it has yet to formulate*! (Porter 1996a) The resolution to this circular conundrum is a role for the Ergonomics Society as well as all practising ergonomists!

In the case of the creation of new plant, production or assembly lines, a financial case will be made to the corporate authorising authority, perhaps the full or regional Board. For a project with several years of life then a widely used and understood investment appraisal tool is "Net Present Value" (NPV). This discounted quantities representing predicted future cash flows are summed to create a single figure merit for the proposal. (Table 1.) In a comparison of two or more projects the one with the largest NPV value is, from a financial perspective, the preferential investment.

Discount rate = 5%	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Cash flow	100	100	100	100	100	100
Cash flow discounted to Yr0	100.0	95.2	90.7	86.4	82.3	78.4
Cumulative discounted cash flow	100.0	195.2	285.9	372.3	454.6	532.9
Net Present Value	**£532.9**					

Table 1. Simplified set of accounts demonstrating how NPV "reflects" future cash flows back to the current year (Year 0.)

The discount rate will usually be set, according to company policy, and related to the cost of equity capital available. Thus for a perfect, risk free, business, *Bank-base* or long term *"gilts" rate* is commonly adopted as a starting point. Alternatively a prediction of the FT All Share Market Index may be used as, this too, represents an approximation of a risk free investment. However, more likely the base-rate will be increased and a "hurdle" rate set, for internal use, by the business itself.

In the case of a project where a need for ergonomics might be expected the impact of this should be explicitly built into the financial model. The discount rate should also be manipulated to add an appropriate risk premium to the calculations to make allowance for unexpected and uncontrollable events and circumstances. The magnitude of this factor will depend upon both experience and policy. The *Fisher effect* (1 – 3 overleaf) is used to incorporate all the un-quantifiable risk into the model, thus the actual value adopted is dependant, in part, upon a prediction of how the ergonomist will reduce the risk of undesirable outcomes.

For example, an ergonomist might be able to make a effective reduction in the musculoskeletal injuries rate or in the level of claims for work-induced-hearing loss expected among those working on the proposed assembly line. This would reduce costs and liabilities due to poor workplace and task design. These savings and the control of undefined risk, could create strategic advantage for the organisation and its products. (Porter 1998b)

$$\text{Discount rate}(\%) = \text{risk free rate}(\%) + \text{risk premium}(\%) \quad (1)$$

$$(1+ R/100) = (1 + rf/100) \times (1 + rp/100) \quad (\textit{Fisher effect}) \quad (2)$$

$$\text{Discount rate } (R) = ((1 + rf/100) \times (1 + rp/100) - 1) \times 100 \quad (3)$$

It would also be prudent to include in the cash flow model a sum for ergonomic design, perhaps associated with a negotiated reduction in the employers liability insurance or reduced labour costs associated with turnover and ill-health. Consider a proposal to create a new production facility in an organisation that uses a risk rate of 5% and would normally add a premium of a further 5%. Using equation (3) gives a Discount rate of 10.25%, Table 2.

Discount rate = 10.25%	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Development and Capital Costs	(100.0)	(145.0)	(50.0)	0	0	0
Production Costs	0	(5.0)	(12.5)	(12.5.0)	(12.5)	(10.0)
Sales Revenue	0	50.0	125.0	125.0	125.0	100.0
Cash Flow	(100.0)	(100.0)	62.5	112.5	112.5	90.0
Discounted Cash Flow	(100.0)	(90.7)	51.4	83.9	74.1	55.3
Cumulative Discounted Cash Flow	(100.0)	(190.7)	(139.3)	(55.3)	(20.8)	76.1
Net Present Value	**£76.1**			[All figures £k]		

Table 2. Summary project accounts and NPV (£k)

The HSE musculoskeletal risk assessment tools, usable by non-specialists, support an ergonomic intervention by identifying risk factors and by indicating possible control actions. (Graves et al 2004) At present, the HSE's tools do not support the quantification of the risk but an ergonomist could (HSE 2002).

If for example an ergonomist was to be involved in assembly line design then the risk premium might, it could be argued, be reduced by 0.5%. The risk premium is dropped, the discount rate becomes 9.73% and, if other factors are unchanged, the project NPV rises by £4k (>5%) (Table 3.). The discounted payback also occurs a year earlier.

Discount rate = 9.73%	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Cash Flow	(100.0)	(100.0)	62.5	112.5	112.5	90.0
Discounted Cash Flow	(100.0)	(91.1)	51.9	85.2	77.6	56.6
Cumulative Discounted Cash Flow	(100.0)	(191.1)	(139.2)	(54.1)	23.5	80.1
Net Present Value	**£80.1**			[All figures £k]		

Table 3. Summary project accounts (revised) and NPV (£k)

Net Present Value is a common evaluation projects tool but there are caveats, including:

- A model is only as good as the assumptions/predictions within it. For example, sales data estimates may be especially imprecise if the market or product is new.
- Unless particular intelligence is available the model will assume the status quo for the competitive environment when, in practice, it is dynamic and will respond. For example, the assumption that resulted in an erroneous (for some) decision to build the Channel Tunnel was that the Ferries would not reduce, in real terms, their prices. This proved not to be the case.
- Undue prominence may be given to the cash-flows (often negative) in early years and this "downgrades" the importance of the taking a longer view of the project
- In "long" term the discount rate can reduce later cash-flows to insignificance.
- It is important to consider risk and uncertainty implicitly unresolved in the model. Manipulate the discount rate as well as make changes to specific model elements.
- There is an, unlikely, assumption that the accuracy of prediction is as reliable in the short term as it is in the long. This is, to some extent, balanced by the "short term" focus of the measure.
- Sensitivity and scenario modelling should be undertaken to support decision making associated with NPV analysis. It is essential to consider which variables are critical, which independent and which interconnected.

It is possible to model the effect of various scenarios that might be outlined. For example, a particular industry, such as clothing manufacture might have prevalence rates of musculoskeletal injury among staff of 18 per 200,000 hours (approximately a factory of 100 working for a year) but, following the intervention of an ergonomist this figure might be cut to 1/3 although there will also be costs to product rates and workstation design to balance against lost production legal claims and other associated costs (Porter 1995).

Ergonomic evaluative techniques/tools (eg REBA (McAtamney and Hignett 1997) can be applied to mime exercises and role-playing evaluations with full size rigs and mock-ups to provide indicators of potential musculoskeletal problems prior to the creation of the workstation and associated task.

NPV analysis can readily applied to such situations. A particular assembly line had musculoskeletal prevalence rate among the workforce of 11.8%. Based upon previous experience the ergonomist was able to propose the following probabilities for the, generally, improved rates obtainable once improvements had been made.

		MSD (%) rate (annual)	NPV (5 years)	
	Initial predication	11.8%	£40.67M	NPV multiplied by confidence
	Predicted (10% confidence)	2.4%	£90.9M	£9.1M
	Predicted (50% confidence)	3.5%	£85.0M	£42.5M
	Predicted (20% confidence)	5.9%	£72.2M	£14.4M
	Predicted (10% confidence)	7.1%	£65.8M	£6.6M
	Predicted (5% confidence)	8.9%	£56.1M	£2.8M
	Predicted (2.5% confidence)	11.8%	£40.6M	£1.0M
	Predicted (2.5% confidence)	14.8%	£24.6M	£0.6M
		Composite NPV		£77.0M

Table 4. Summation of NPVs following various predicted musculoskeletal disorder rates and associated probabilities following an ergonomic intervention.

In the case described scenario analysis was undertaken which included additional labour and *line-balancing* costs were included in the model as were allowances for "litigation management" and settlement. The model included a small risk that MSD rates will rise (and NPV fall) as a result of the intervention, overall the prognosis is that the business will benefit considerably.

New Product Development

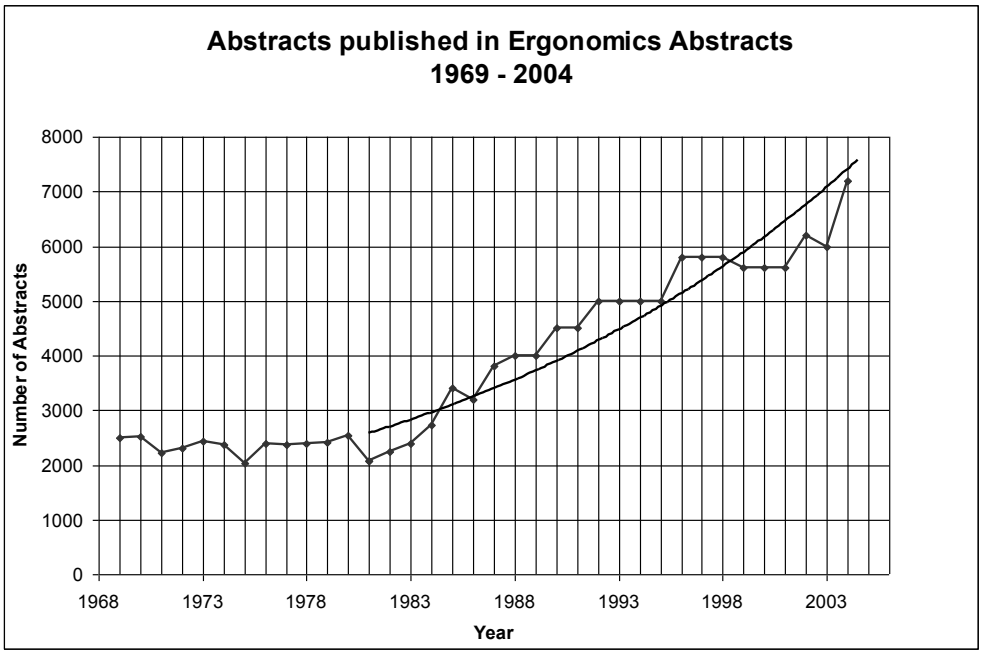
New product creation is an area of activity in which ergonomics must make a contribution but where it has often failed to justify the benefits associated with the intervention. In marketing to consumers attention is often drawn to the real and perceived "good" ergonomics of the artefact. However, this use of the term is often questioned by ergonomists, not least because the marketing statement refers to only limited aspects of the product which may also include some ergonomically problematic design features. The car, described as "ergonomically designed" might have an effective driving position with respect to the controls, displays and seating may be capable of adjustment to suit, 65% of a specified population. However the car has "blind spots" and a boot that, once opened, can only be easily reached by females of 95%ile stature or more. It is only ergonomically good "in parts". If the design was then offered for sale in Malta could the design still be described as "ergonomic" given the significant anthropometric differences between the *design for* and *sold to* populations?

Pioneering Industrial Designers such as Raymond Loewy (Schönberger 1991) and Henry Dreyfus would work on diverse product ranges from cars to trains and from crockery to refrigerators and retain overall creative control. Their products pushed forward the *American Dream* in a way that others, such as Bill Mitchell and Sir William Lyon who styled cars only contributed highlights. (Lyon was working in Britian but his Jaguars were with the American Market in mind and applauded on both sides of the Atlantic.) The impact of contemporary architects and interior designers on the office environment, often a focus for the ergonomist has been highlighted (Albrecht and Broikos 2001) The pre war excitement of applying technology to life was summed up in the slogan for the 1936 Chicago World's Fair - *Science Finds, Industry Applies, Man Conforms.*

These designers had contemporaries who were founding ergonomists such as Alphonse Chapanis (1999), Paul Fitts, Hywell Murrell, and Brian Shackel. These pioneers worked on fundamental research but were also concerned with applying their insights to both business and technology.

Thirty or forty years ago when, although I did not yet know the term, I was first considering becoming an ergonomist the technological world was very different to today. There is more computing power in an obsolete 1990s mobile phone than the onboard "Mission Critical" computers of an Apollo Space Craft. Indeed, until the pause caused by the 1986 Challenger Disaster, the Space Shuttle flew with magnetic core memory, developed in the 1940s rather than silicon chip based memory. A "3G" Cell Phone will contain more than 4000 times the memory that the ICL1900 Computer used at Sussex University 35 years ago. A time when "walkie talkie", not mobile phone, technology was the, highly restricted, mobile communication service available and recorded music was played without the need for laser technology. This was before "post-its", Dyson vacuum technology and the take-up of the "workmate" by Black & Decker. "The Whole Earth Catalog" was still privately printed by the creator (Brand 1968); Applied Ergonomics and Ergonomics Abstracts were both founded. The UK's Ergonomics Research Society would shortly drop *Research* from its name.

In 1969 Ergonomic Abstracts was first published. It had about 2250 entries for the first 15 years but today, the number of entries has increased three-fold and is still climbing. In 1969 it indexed articles from 150 primary serial publications and today that has more than doubled at 338. (Graph 1.) Among other emergent properties of this growth in activity is a partitioning of ergonomists to two broad categories; those that select and specialise and those that adopt a wider *General Practitioner* role. The latter ergonomists are often the first contact for others seeking help and they should *treat* or *refer*, as appropriate. To be successful *they must know what they don't know and also who knows what they don't know!*



Graph 1. The rise and rise, especially since 1980, of ergonomic activity, as indicated by the number of abstracts published each year in Ergonomics Abstracts.

Thus, until recently individuals would often be the "controlling mind" for a locomotive car design project or the creation of an aircraft cockpit and not just for some inventions still distant from the marketplace. Today the designed world is, in most cases, too complex for a single controlling vision, teams are required to provide sufficient variety to match the complexity of the task and teams, themselves, require co-ordination, integration and focus.

There is still the role of the lone inventor creating the new and the novel but for most development teams acceptable solutions can only reach the marketplace in a timely fashion via richly interconnected groups of specialists working with common purpose, time-scale and resources. Today, more than previously (cold-war weapons excepted) designed products should function, *acceptably,* immediately from launch; even if a new, "improved" artefact quickly follows[1]. The consumer also plays their part by *trusting* the design team and the *brand* (Ollins 2003) to the extent of purchasing without trial. In many cases the item purchased represents a significant cost to the family; a decision which cannot be reversed without significant loss.

[1] For some businesses the strategy of rapid change/improvement is seen as an alternative to the creation and defending of Intellectual Property Rights – by the time competitors see what is available in the marketplace the improved version is in production.

To cope with the increase in complexity of the designed world and the drive for the minimisation of the time from idea to marketplace various "lean design" and "rapid prototyping" strategies have been developed and employed. The creation of production strategies that deliver "just-in-time" (JIT) has proliferated since they were first devised in response to the constraints established by General Douglas MacArthur who was managing the reconstruction of Japan after World War 2.

The tension between JIT and a cost minimisation strategy demands that manufacturing takes place where labour is cheapest and gives rise to the drive for flexible, fast, subsidised transport. Design teams respond to this context by considering the impact on the design solution of extended supply chains, diversified markets and manufacturing locations. The resistance to this *distributed* business strategy is limited. Governments' rarely seek a *fair* return for the infrastructure demanded and the environmental damage done by transportation. Europe, for example, only lightly taxes aviation fuel but this still makes it amongst the highest priced regions in the world at nearly 20p per US gallon (~3.8L) in mid March 2005.

In the simple helical (*linear*) mode of product development, where brief/idea leads to concept and thence to technical realisation, design realisation, prototypes, design for production, marketplace review and redesign, time may be found for the ergonomist.

Early in the process the ergonomists may provide basic data about the abilities of people, conduct experiments to obtain better data than can be found in publications. Later, they conduct overview evaluations, field trials, *Hall Tests* and, generally, evaluate the usability of prototypes. In due course they might review the product and help create the design brief for the next version. (Diagram 1.)

At this time other ergonomists may be creating and justifying their involvement via NPV predictions, with production engineering, the manufacturing *flo-line* and workstations on which the product will be made. Later, other ergonomists might undertake evaluation of the product and report upon its ease of use, safety and general desirability.

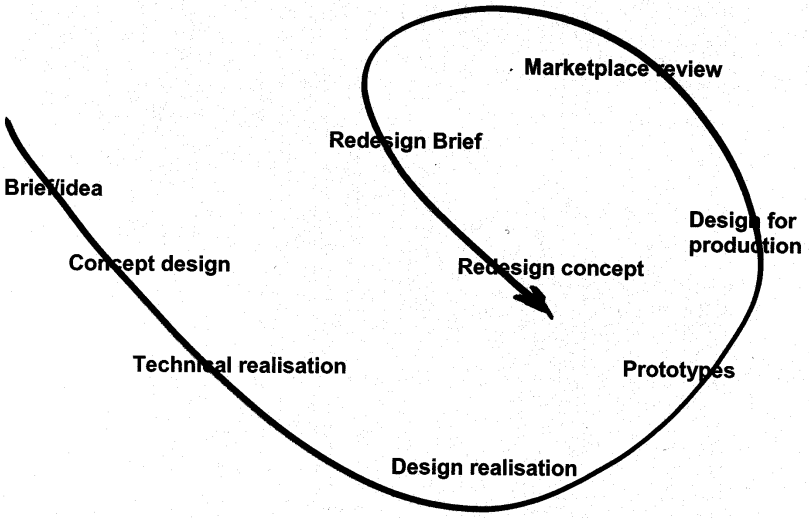


Diagram 1. A traditional, helical view of product development/engineering design. The pace of activity provides time for a considered ergonomic perspective and evaluation within the design process.

Today it is common for the various stages of design process to be fused and those that are not to occur in parallel. (Diagram 2. overleaf)

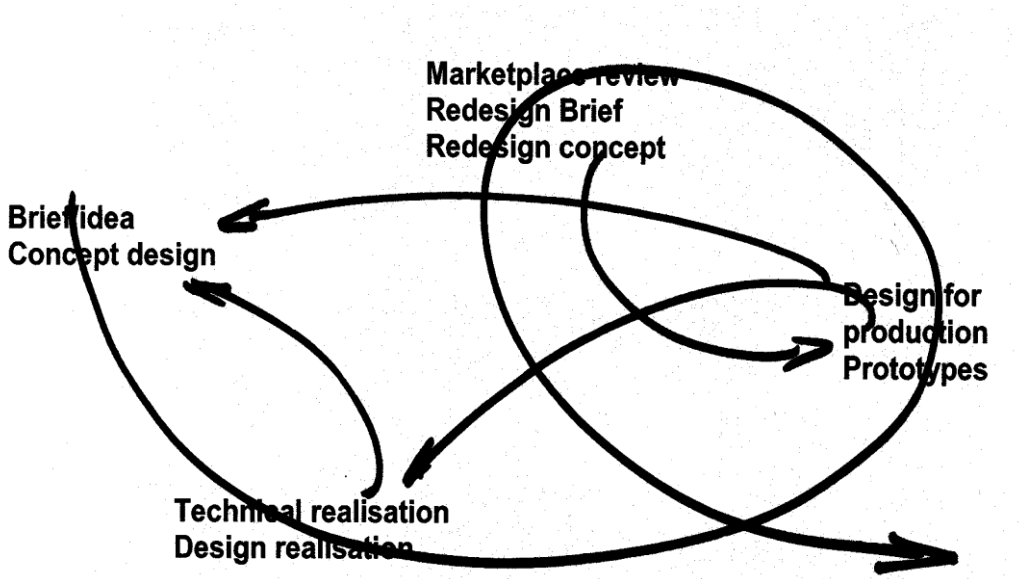


Diagram 2. A current perspective of the "lean", "team based" product development process.

The role of the design team has also expanded recently to the extent that they are less focused upon the artefact alone but to consider it in the context of the systems and behavioural/cultural environment in which it will be used. The designer might, for example, create a microwave oven without reference to the types of ready meals offered by supermarkets or seek to integrate the power levels offered with those specified on the meals. The discrete roles underpinning the product development model Diagram 3. are now, more commonly integrated, Diagram 4. (Porter 1996b)

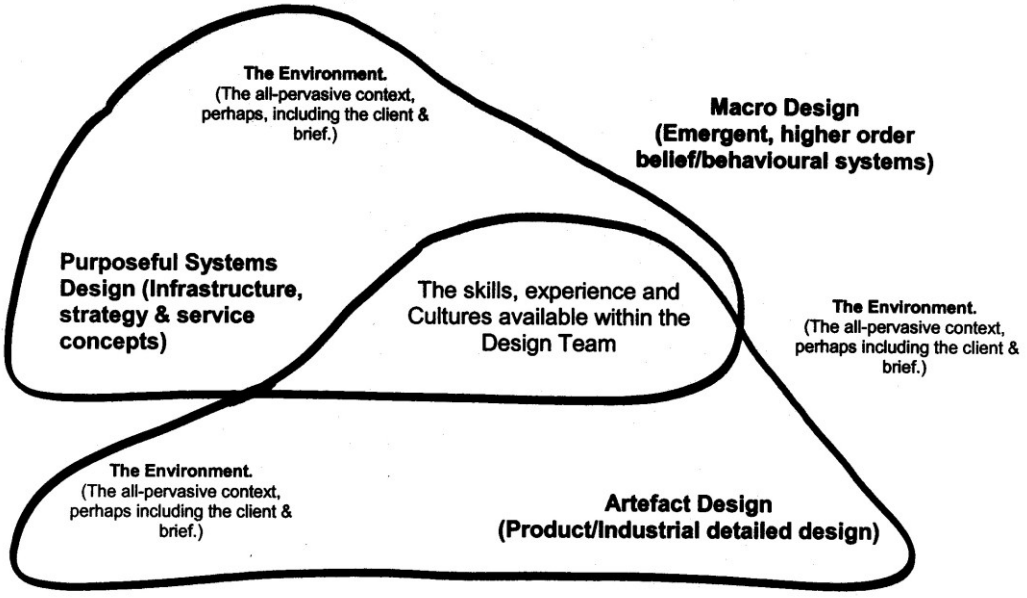


Diagram 3. A traditional view of the design realisation to market process. The Product Designer works to a brief which is, largely, without detail concerning the systems that will engage with the product once sold.

Diagram 4. shows a revised view for which numerous contemporary examples can be presented. For example, the iPod may be viewed as an *exquisite* item of product design (although it has been plagued with technical issues associated with its batteries) but is, in reality, only part of a music distribution system which may be identified as the more significant revenue stream. Furthermore, as a "must have accessory" in the *tribe* it has had a profound influence on belonging, style, acceptance, etc of one individual by his/her peers. Look at the *holsters* and covers made by the fashion houses for iPod and you will see how the product can be made to fit in with the norms of other *niche groupings.* It is also interesting to note that design of the interface was undertaken by product designers who did not undertake major Human Factors trials least details of their, *highly self-applauded,* prototypes and associated music distribution system leaked to competitors (Ive 2003). The iPod is an example of a product where good ergonomics is incorporated with fine design and together they *sell* profitable products. Ergonomics pays!

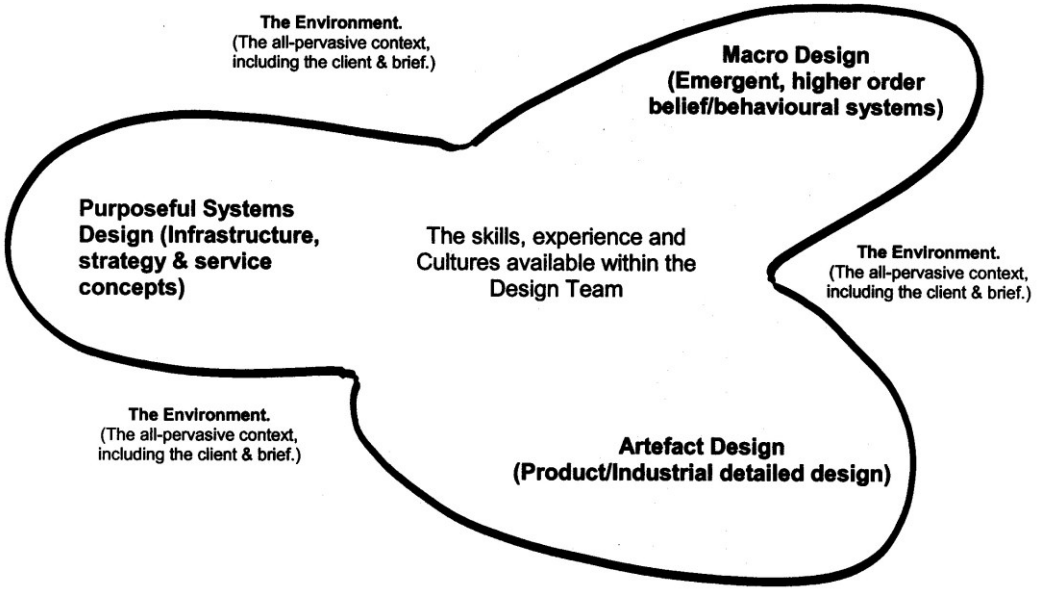


Diagram 4. A design paradigm in which the creative process covers the artefact, the systems that engage with it and it's impact upon culture and behaviour.

Ergonomists need to be sensitive to the impact of their contributions and that of the product they seek to influence. Improving car driver safely, for example, might encourage those that seek a particular level of adrenaline to seek greater acceleration, drive faster, brake later and thus risk the safety of other road users. A new mobile-phone might be better with fewer functions but enhanced usability by those with poor hearing. Solutions might be sought for the selection problem of a person seeking to choose their preferred evening viewing with a TV service offering 50+ different channels/options.

Ergonomists might wish to take a wider perspective but many businesses are financially successful with products who's usability could readily be improved. Camera's with backs that come open and thus ruin the film when they are put into the case or others which can be switched on, and the battery emptied, while carried by its strap and hanging off the shoulder. *Boomboxes* whose displays and controls are difficult to identify and operate or flat-packed furniture that is too heavy, for most, to unload safely from a car roof rack, sofas and child car seats that are not comfortable in use, finger-cutting tins and awkward tin openers…. Regrettably, products can often be described as successful and may even win awards, when the ergonomics are, at least in part, sub-optimal!

The American website http:///www.baddesigns.com (20/03/05) has an extensive range of similar examples. However, should not all practising ergonomists and *The Ergonomics Society,* be doing more to highlight those products with ergonomic shortcomings? Is this especially important for artefacts marketed with reference to the quality of ergonomics incorporated in the design? Is it sufficient to rely on those practising in this field and the perspective emerging from the Society? Should the www.ergonomics4schools.com website take a lead and devise materials for use in schools and thus, explicitly, seek to educate the next generation of consumers?

What ergonomists can, and should do, during their engagement with the Design team is to specify the desirable usability and how that might be tested (Porter 1996b). Working with the design team, and especially those responsible for the marketing, they should ensure that the brief contains targets that are responsive to the benefits that might be gained from an input of ergonomics into the product and its subsequent positioning within the competitive environment. Supporting these details helps create the data needed for the NPV appraisal calculations and thus ensures that good ergonomics/usability is part of the design solution offered for sale, the production process and the ancillary support services.

The *Target Costing* concept is an important driver of the design brief, the design teams response. It should accurately represent the expectations that ergonomics can offer in the market; albeit an element that is often hidden to those that cannot or will not evaluate the product prior to purchase. Examples of the marketplace factors involved in a target-costing model are shown in Diagram 5. Again, generally, the cost of the ergonomics input is small in comparison to other costs such as mould making, establishing assembly lines, transportation between manufacturing plant and the marketplace, etc. When the sensitivity analysis is undertaken with the NPV model the launch date is often seen to be critical for the profitability of the product as may the response of the competitors. Sufficient product in retail stores in November enables the Christmas market to exploited while a, delayed, January launch does not.

The Ergonomist's Role
In general the broad roles usually identified for the ergonomist are:

- Creating new knowledge/understanding by original research
- The evaluation of existing artefacts/workplaces/applications/systems from a usability perspective and subsequent dissemination (often internal to the client organisation) of these analyses
- The creation of tools/techniques to support the roles of all ergonomists
- The predictive role assessing artefacts/workplaces/applications/systems that are yet to exist and the championing of the process necessary for the timely adoption of change
- The subsequent dissemination (publication) of these insights both among both the ergonomics and the business communities

The balance of roles varies but, historically, the first three are more common than the latter two; especially dissemination outside the ergonomics community. However, in the design of future products, the promotion of workforce health, safety and productivity and the prevention of catastrophic failure ergonomics has a, financially justifiable, role to play. Unfortunately, ergonomist's usually prefer to work via feed-back control rather than the mode necessary for new developments. feed-forward. Designers, Architects, Engineers prefer, predictive, feed-forward control and accept that errors will be made that necessitate modification or reworking.

Target Costing - An Example

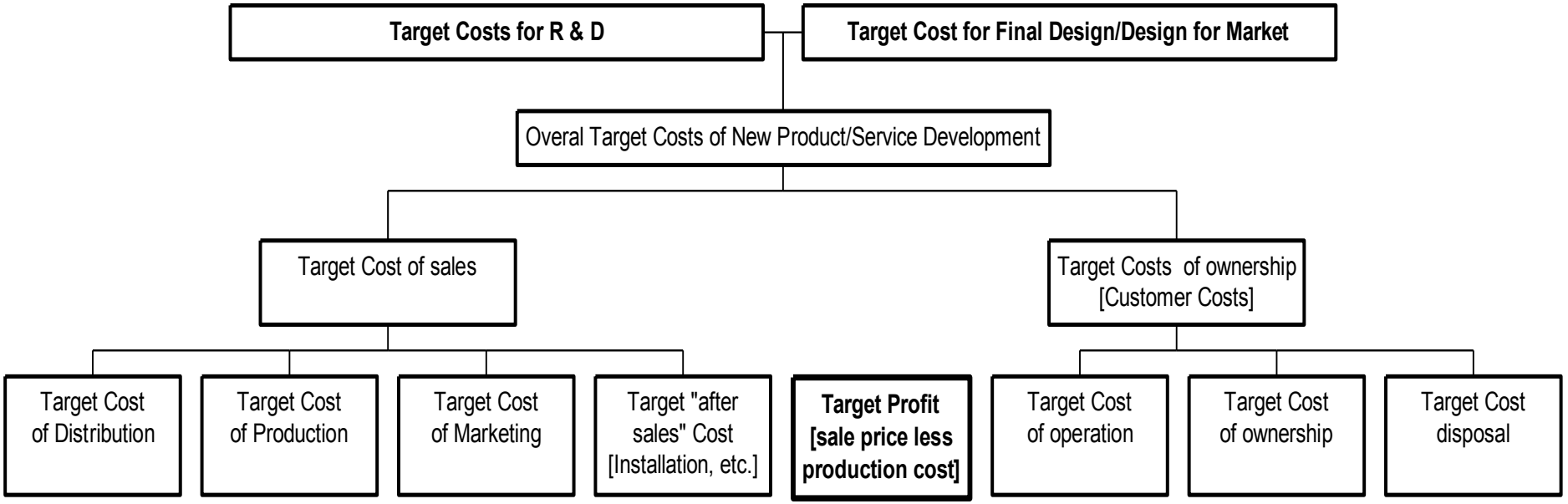


Diagram 5. An overview of the factors involved in the *Target Costing* of a product designed for domestic use. These figures, once quantified, are used as variables in the NPV appraisal of the project. Note that the degree of certainly, and confidence, associated with each figure will vary and that the *Product Champion's* experience of the market will be an important factor. It would be prudent for the organisation, and the design team, to undertake sensitivity analysis to establish the robustness of the NPV based decision to preceded, or not, to the product launch in the (selected) marketplace.

Conclusion

Increasingly, those ergonomists seeking to influence the real world via the design process are finding that they have the skills required to foresee issues and to engage the design team purpose to satisfy or exceed the set brief. However, they will only influence the designed environment if they use the tools available to support their insights, quantify risk and thus trigger change. Financial project appraisal, via NPV modelling and the associated sensitivity analysis can be used to justify an ergonomic input into design to those setting the brief and championing the response.

Whether it be a catastrophic failure of a human-activity system, a production line where musculoskeletal injury is too likely, or a product that causes dissatisfaction when it fails to work intuitively, the result is money "wasted". These problems are resolvable and ergonomists can contribute important insights to enhance the solutions considered. The cost of their contribution, and that of the full design team, is usually only a small element within the NPV appraisal. However, the rewards are, potentially, significant. In the language of business, the contribution of the ergonomist should be, *highly geared.*

However, many ergonomists feel insecure promoting their views and working in a predictive feed-forward mode. Unless they overcome this limitation they will miss many opportunities to improve the usability of the designed world and find it increasingly difficult to engage in design teams working to create the world of tomorrow. In this context it must be noted that another person included in the design team adds to the variety and makes co-ordination and communication more difficult. The contributions of another professional will only be welcomed if, demonstrably, benefits that otherwise would not arise can be secured. It is also true that, today, the design team lacking an ergonomic perspective is missing an opportunity for competitive advantage that their competitors might be exploiting. The promotion of these potential benefits is not only the responsibility of all ergonomists but also of the Ergonomics Society, the sponsor of today's workshop.

One issue of the (cultural) mismatch between practising ergonomists and members of the design team is the responsibility of those that create the ergonomists of the future. Students of design, and architects in training, will find themselves frequently presenting and justifying their ideas and views of the future. Such, perhaps weekly, *crits* will build the confidence the *creatives* expect to see in those that they work with. In these "hot-house" environments ergonomists can appear restrained, tentative and lacking the expected confidence in their insights; simply because they are not as practised at giving presentations as the designers might expect.

In getting products from idea/brief to market many organisations make use of *a Product Champion.* The time has come for ergonomics to have Champions to promote our inclusion throughout the design process. Now that is something we should all be promoting!

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